

MAC-layer Approach for Cluster-Based Aggregation in Sensor Networks

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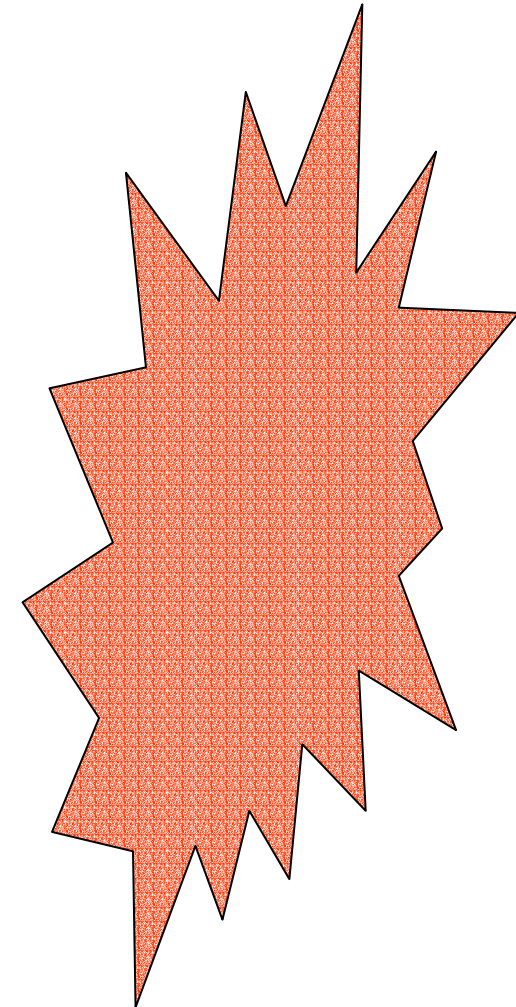
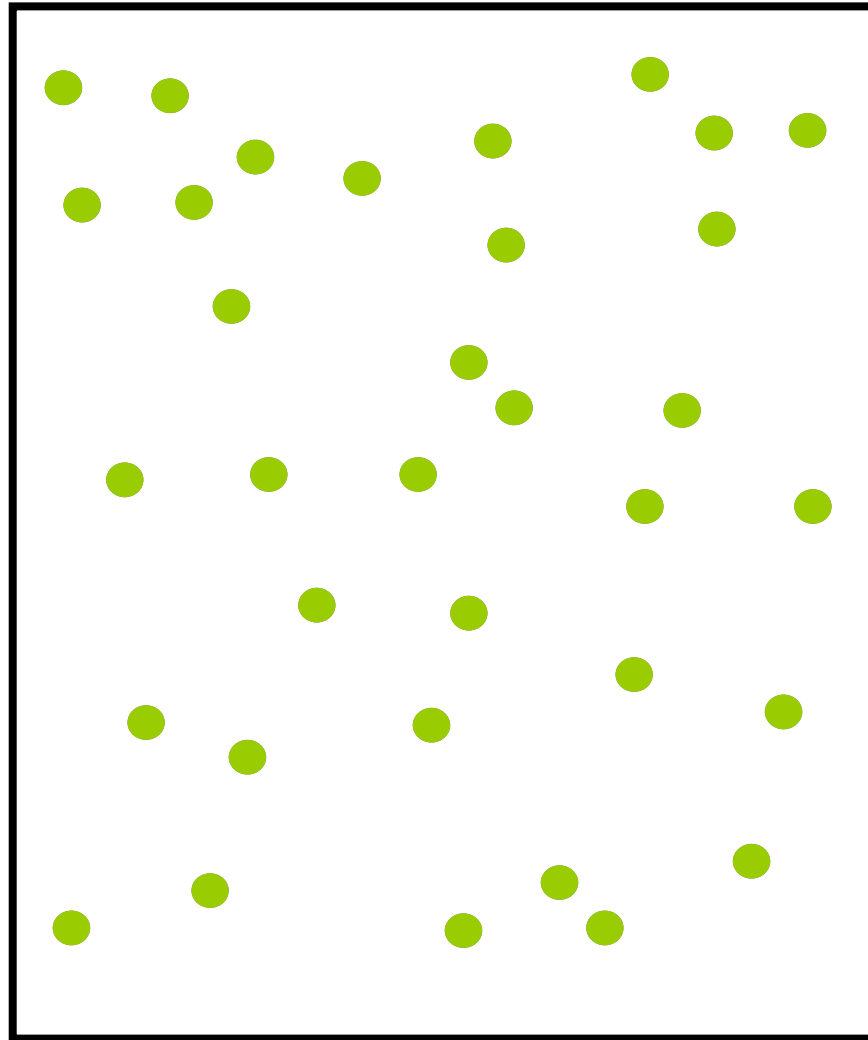
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- Introduction & Problem definition
- System Model
- New proposed Algorithm
- Results
- Conclusion and Outlook

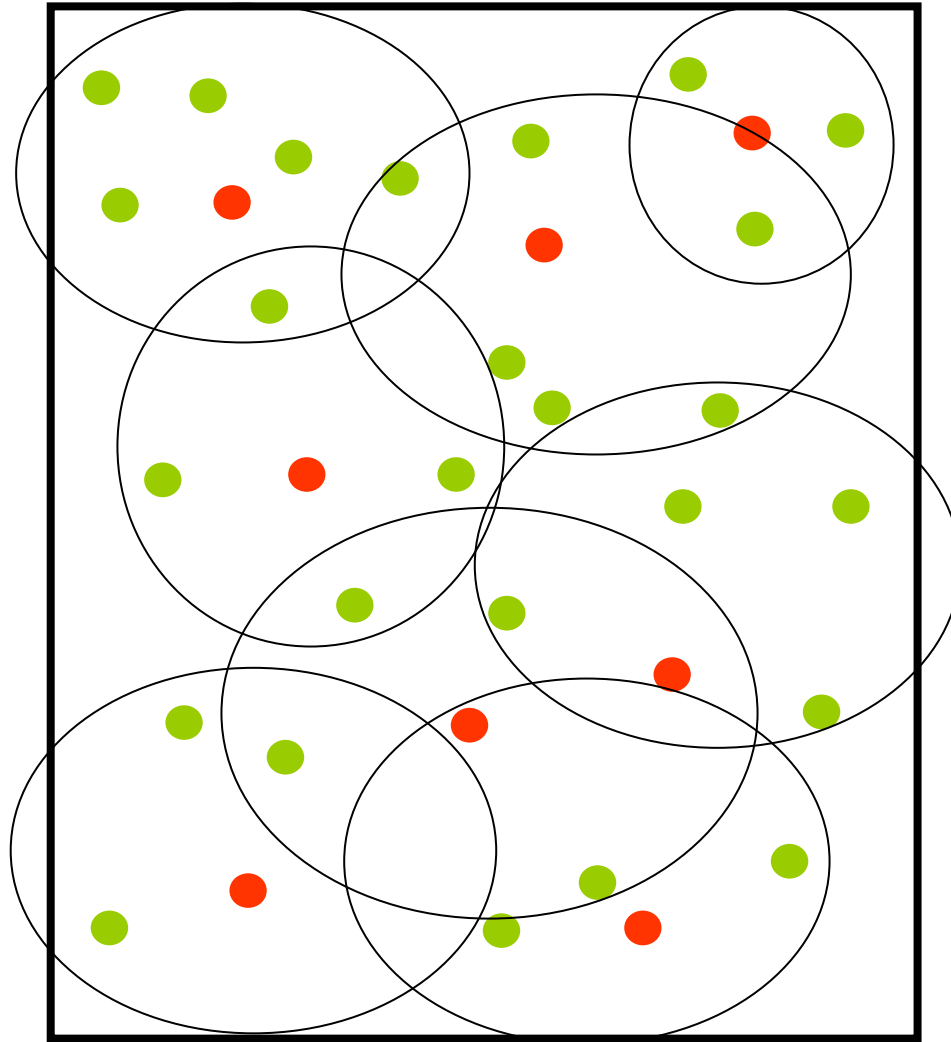
- Sensor Network
 - Sensor field for monitoring and surveillance
 - Large number devices, unattended deployment
 - Device
 - Tiny device with lightweight wireless transceiver
 - Limited Energy (irreplaceable battery)
 - Physical Sensor (defines the measurable attributes)
 - Wireless sensor network is instantiated through the collaboration among the nodes in order to fulfill a larger sensing task

- Features of the sensor network
 - Data-centric style of communication
 - Directed diffusion – inquirer expresses interest, sensor that match the required attribute send replies
 - Bootstrap procedures for network self-assembly
 - Data aggregation
 - The nodes which are data aggregators should be active upon arrival of query

Problem definition – node wakeup

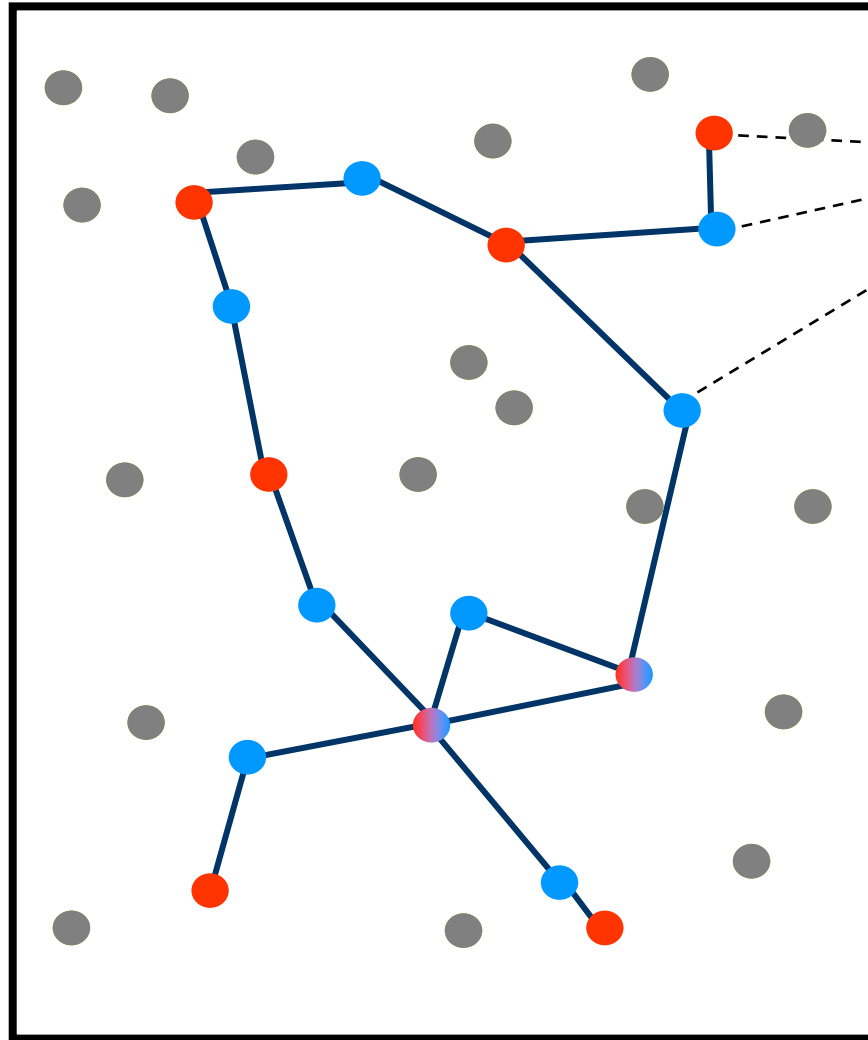


Clustering and data aggregation



Clustering an aggregation of data

- Clusterhead
- Bridge
- Clusterhead/
Bridge
- Terminal in
sleep mode.



The sink should connect to at least one active node. Then the complete data is available through the network

Approach to the problem

- Why each node does not send the data to the sink upon triggering?
 - Excessive contention
 - High transmitting power
 - The sink does not need the data from all nodes
- Three sub-problems for clustered solution
 1. How to access the wireless channel upon wakeup
 2. How to organize the nodes into interconnected clusters
 3. How to store all the data in the created sensor network
- Cross-layered approach

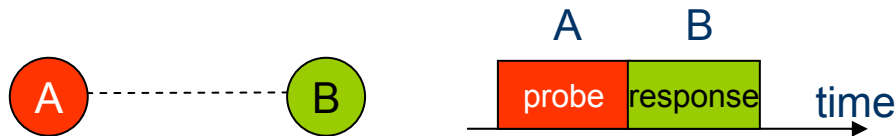
- Channel types
 - Rendezvous channel (R-channel)
 - Communication channel
- Symmetric radio links
- Synchronization issues
 - Slotted channel assumed to facilitate explanation
 - The probe packets are used as synchronizers
 - Node B replies to node A only after receiving probe
- Collision is the only source of error

Basics of the proposed algorithm

- Node roles in the sensor network
 - Data aggregation: aggregator and contributor
 - Networking: clusterhead, remote, bridge
- Reliable link formation
 - Asymmetric procedure: interrogator and responder
- Cross-layering:
 - Use the roles of interrogator-responder to define the network roles

Reliable link formation – role conflict

- Neighbor discovery and link formation



- Symmetric randomized protocol

- Role conflict defined

- Solved by a leader election procedure

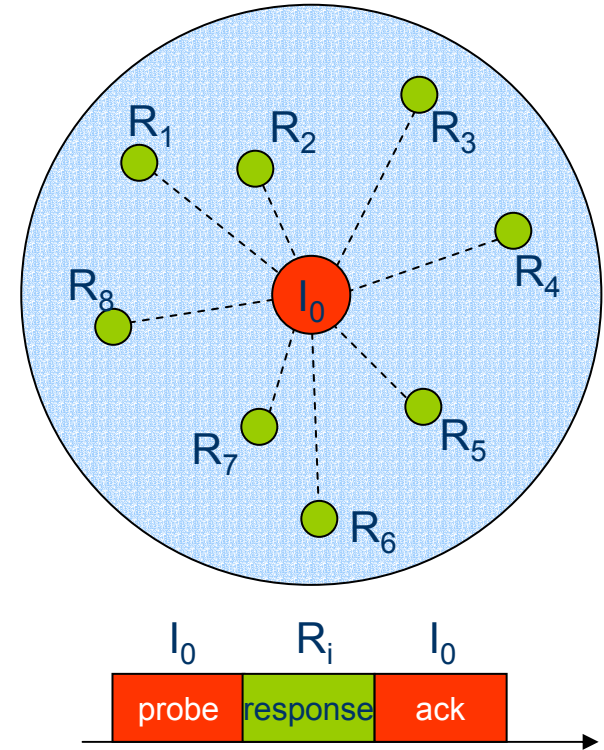
- A node starts to send probe with probability $p = \frac{1}{N_{\max}}$

- This probability is doubled if no reply is received

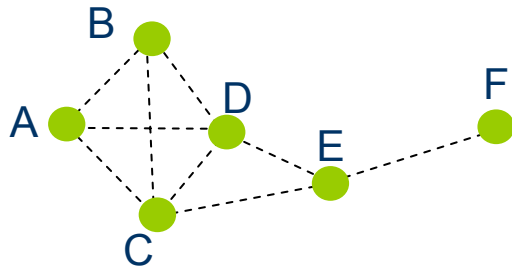
- Collision is also a reply – means that some responder is interested in forming the link!

Reliable link formation – reply conflict

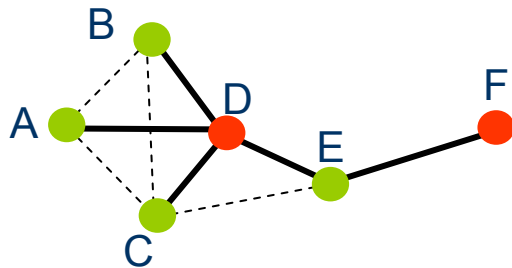
- Reply conflict defined
 - The interrogator resolves the collisions among the responders by a splitting tree.
- Erroneously received probes
 - E.g. when a responder is in range of two interrogators
 - Address adaptation is introduced to rejoin the splitting tree



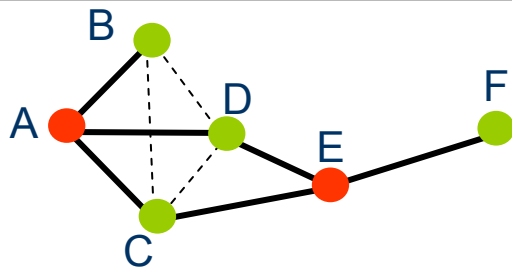
Obtaining a connected network (1)



Example physical topology. A dashed link denotes that the nodes are in range



E must for a link as responder for 2 different interrogators. Alternatively, E can be responder for D and interrogator for F.



The clusters of A and E are connected through two bridges (C and D), although only one is necessary.

Obtaining a connected network (2)

- Local criterion for link formation
 - Avoids exchange of messages at network layer
 - A good candidate for local criterion:

After forming link as a responder, give up further creation of links with probability:

$$1 - \frac{\alpha}{K}$$

α is a parameter
 K is number of known neighbors

- If a node that has only one link as a responder gives up, it goes to sleep.

Role assignment at upper layers

- **At network layer**

- A node that has at least one link as interrogator is a clusterhead
- A node that has links as responder to at least two different interrogators, takes role of bridge
- A node that has link as interrogator, but also has a link as responder, takes two roles: clusterhead and bridge.

NB: We allow two nodes A and B to make mutual link only once, such that it can not happen that A is clusterhead of B and B is also clusterhead of A.

- **At aggregation layer**

- A node aggregates its data in the cluster in which it has formed its first link.
- If a node is first responder and then interrogator, it will be a clusterhead, but not aggregator!

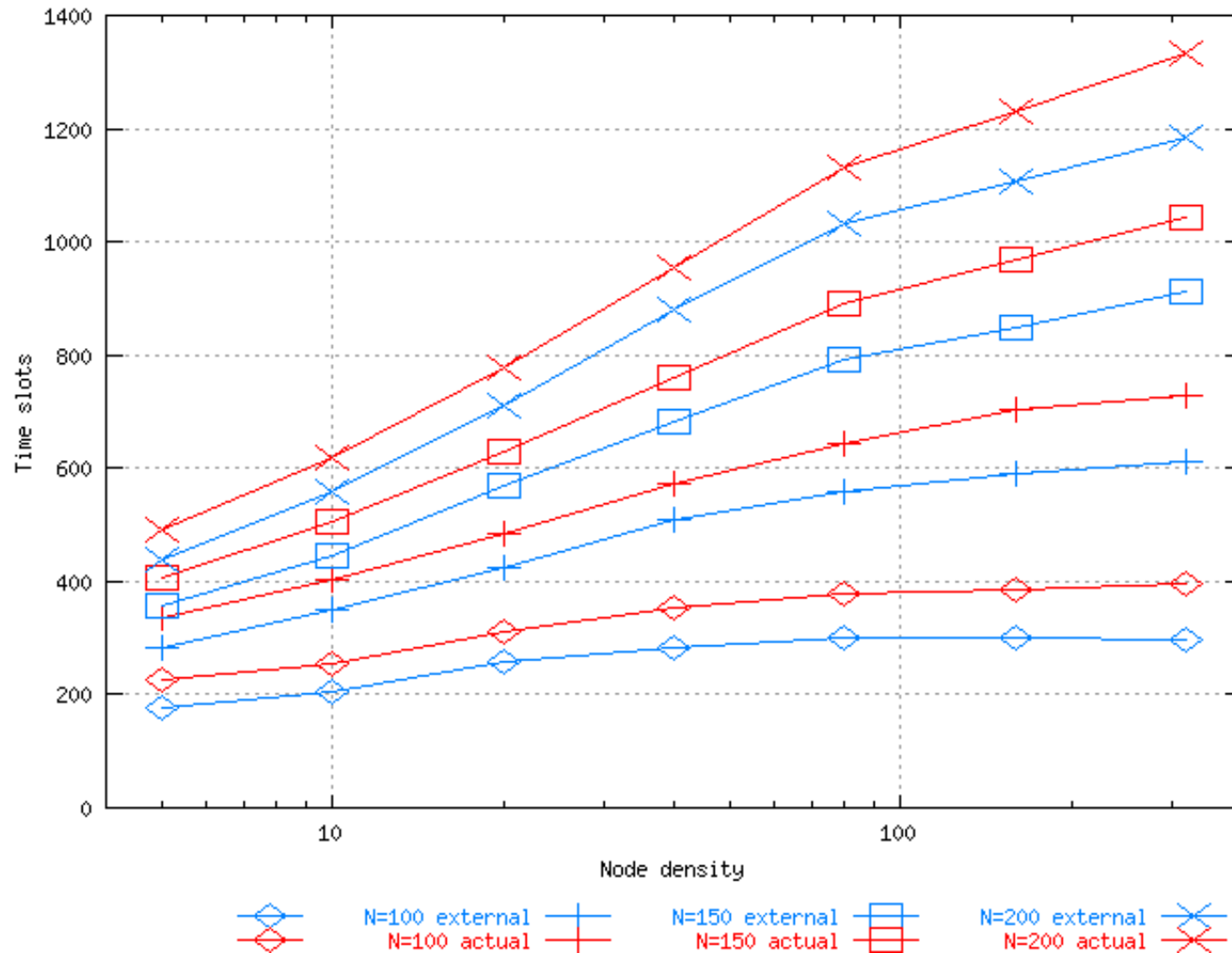
Simulation model and performance measures

- N nodes are uniformly placed in $L \times L$ square
- Communication range R determined from the node density

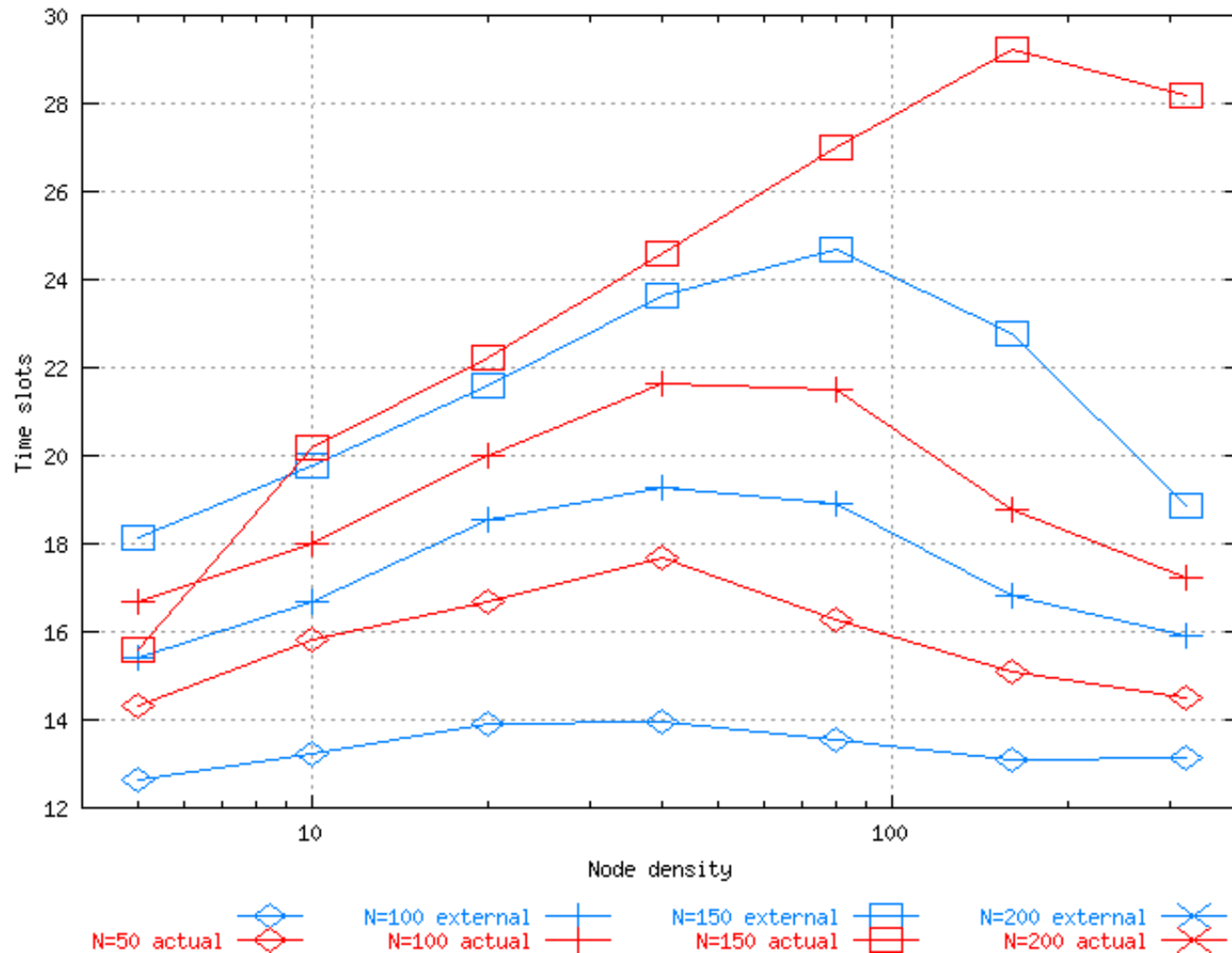
$$\lambda = \frac{\pi \cdot N \cdot R^2}{L^2}$$

- All nodes wake up and start the protocol at the same time
- The duration of the procedure is measured until each interrogator node has sent $P_{\max}=2$ “empty” probe packets
 - When all interrogators stop sending probe packets, no further event can occur in the network creation.
- External observer as a reference

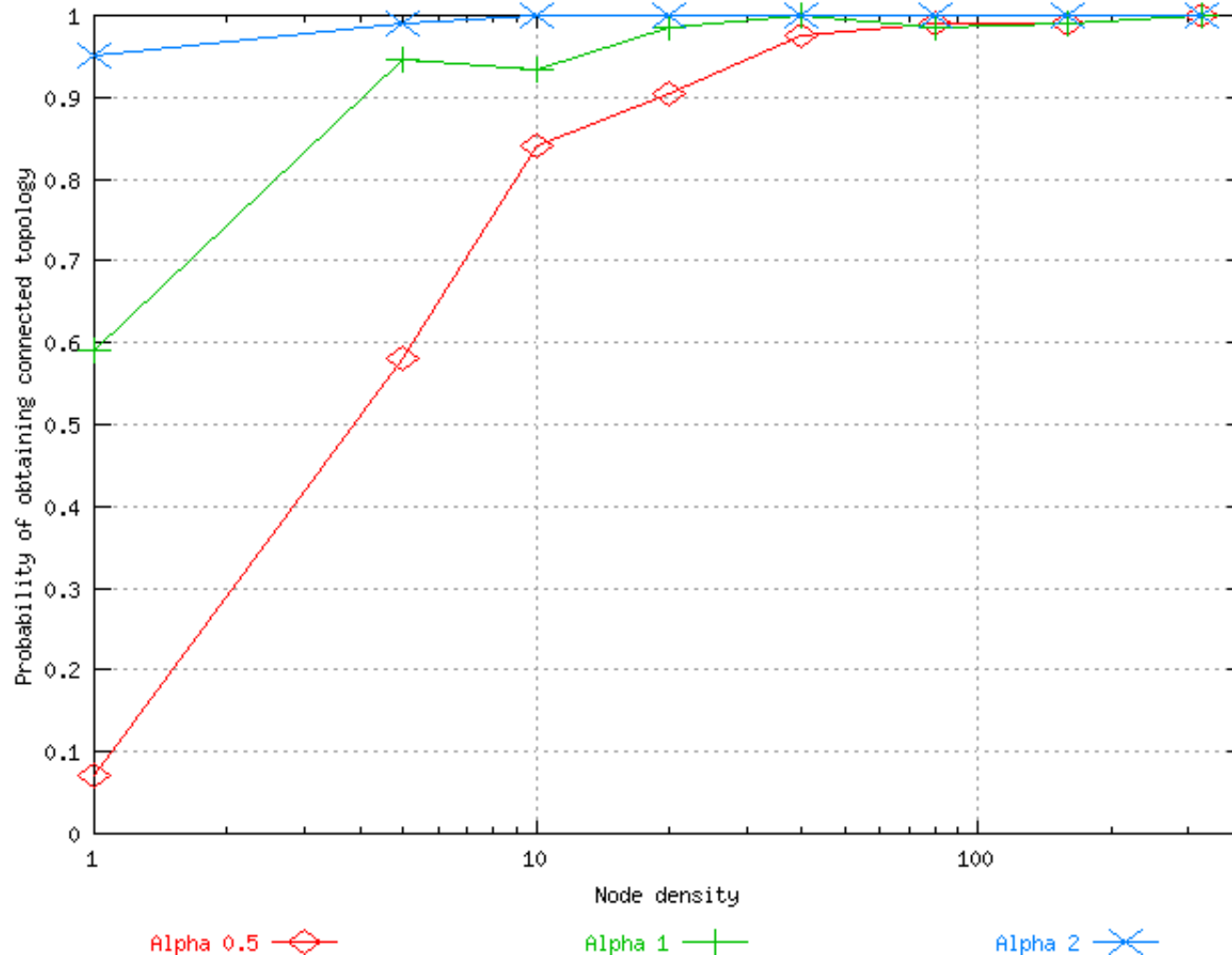
Results (1) – Average duration



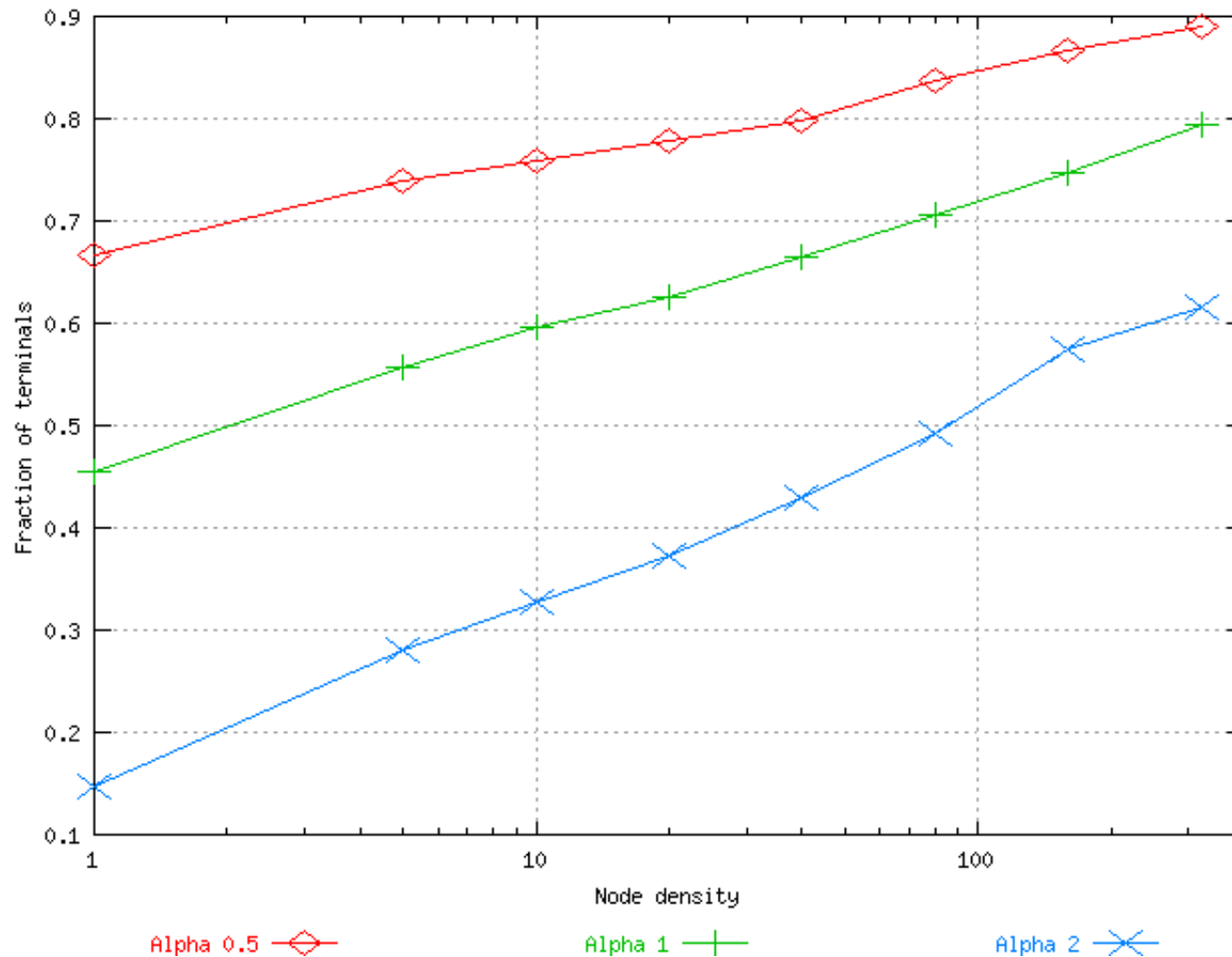
Results (2) – Average number of messages transmitted by a node



Results (3) - Probability of getting connected topology in dependency of alpha



Results (4) – Fraction of terminals in dependency of alpha



Conclusion and outlook

- Protocol for prompt network formation and data aggregation has been designed
 - The proposed reliable link formation deals with excessive contention due to spatial-temporal correlation in sensor activation
 - Cross-layered approach
 - The localized algorithms produce global network property
- Future work
 - Introduce power control during the network formation
 - Analytical approach to the tuning of the parameters in the localized algorithms